GEOLOGIC ATLAS OF THE UNITED STATES

FREDERICKSBURG FOLIO, VIRGINIA-MARYLAND

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

J.W. POWELL, DIRECTOR

GEOLOGIC ATLAS

OF THE

UNITED STATES

FREDERICKSBURG FOLIO

VIRGINIA - MARYLAND

INDEX MAP

SCALE 40 MILES - 1 INCH

AREA OF THE FREDERICKSBURG FOLIO

AREA OF OTHER PUBLISHED FOLIOS

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DESCRIPTION TOPOGRAPHY AREAL GEOLOGY

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EXPLANATION.

The Geological Survey is making a large topographic map and a large geologic map of the United States, which are being issued together in the form of a Geologic Atlas. The parts of the atlas are called folios. Each folio contains a topographic map and a geologic map of a small section of country, and is accompanied by explanatory and descriptive texts. The complete atlas will comprise several thousand folios.

THE TOPOGRAPHIC MAP.

The features represented on the topographic map are of three distinct kinds: (1) inequalities of surface, called *relief*, as plains, prairies, valleys, hills and mountains; (2) distribution of water, called *drainage*, as streams, ponds, lakes, swamps and canals; (3) the works of man, called *culture*, as roads, railroads, boundaries, villages and cities.

Relief.—All elevations are measured from mean sea level. The heights of many points are accurately determined and those which are most important are stated on the map by numbers printed in brown. It is desirable to show also the elevation of any part of a hill, ridge, slope or valley; to delineate the horizontal outline or contour of all slopes; and to indicate their degree of steepness. This is done by lines of constant elevation above mean sea level, which are drawn at regular vertical intervals. The lines are called *contours* and the constant vertical space between each two contours is called the *contour interval*. Contours are printed in brown.

The manner in which contours express the three conditions of relief (elevation, horizontal form and degree of slope) is shown in the following sketch and corresponding contour map:

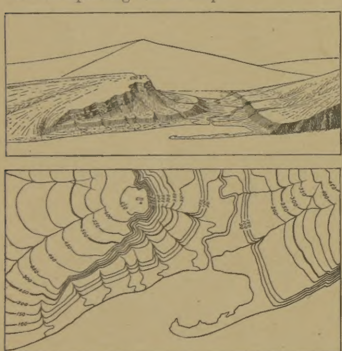


Fig. 1. The upper figure represents a sketch of a river valley, with terraces, and of a high hill encircled by a cliff. These features appear in the map beneath, the slopes and forms of the surface being shown by contours.

The sketch represents a valley between two hills. In the foreground is the sea with a bay which is partly closed by a hooked sand-bar. On either side of the valley is a terrace; from that on the right a hill rises gradually with rounded forms, whereas from that on the left the ground ascends steeply to a precipice which presents sharp corners. The western slope of the higher hill contrasts with the eastern by its gentle descent. In the map each of these features is indicated, directly beneath its position in the sketch, by contours. The following explanation may make clearer the manner in which contours delineate height, form and slope:

1. A contour indicates approximately a height above sea level. In this illustration the contour interval is 50 feet; therefore the contours occur at 50, 100, 150, 200 feet, and so on, above sea level. Along the contour at 250 feet lie all points of the surface 250 feet above sea; and so on with any other contour. In the space between any two contours occur all elevations above the lower and below the higher contour. Thus the contour at 150 feet falls just below the edge of the terrace, while that at 200 feet lies above the terrace; therefore all points on the terrace are shown to be more than 150 but less than 200 feet above sea. The summit of the higher hill is stated to be 670 feet above sea; accordingly the contour at 650 feet surrounds it. In this illustration nearly all the contours are numbered. Where this is not possible, certain contours are made heavy and are numbered; the heights of others may then be ascertained by counting up or down from a numbered contour.

2. Contours define the horizontal forms of slopes. Since contours are continuous horizontal lines conforming to the surface of the ground, they wind smoothly about smooth surfaces, recede into all reentrant angles of ravines and define all prominences. The relations of contour characters to forms of the landscape can be traced in the map and sketch.

3. Contours show the approximate grade of any slope. The vertical space between two contours is the same, whether they lie along a cliff or on a gentle slope; but to rise a given height on a gentle slope one must go farther than on a steep slope. Therefore contours are far apart on the gentle slopes and near together on steep ones.

For a flat or gently undulating country a small contour interval is chosen; for a steep or mountainous country a large contour interval is necessary. The smallest contour interval used on the atlas sheets of the Geological Survey is 5 feet. This is used for districts like the Mississippi delta and the Dismal Swamp region. In mapping great mountain masses like those in Colorado, on a scale of $\frac{1}{250,000}$ the contour interval may be 250 feet. For intermediate relief other contour intervals of 10, 20, 25, 50, and 100 feet are used.

Drainage.—The water courses are indicated by blue lines, which are drawn unbroken where the stream flows the year round, and dotted where the channel is dry a part of the year. Where the stream sinks and reappears at the surface, the supposed underground course is shown by a broken blue line. Marshes and canals are also shown in blue.

Culture.—In the progress of the settlement of any region men establish many artificial features. These, such as roads, railroads and towns, together with names of natural and artificial details and boundaries of towns, counties and states, are printed in black.

As a region develops, culture changes and gradually comes to disagree with the map; hence the representation of culture needs to be revised from time to time. Each sheet bears on its margin the dates of survey and of revision.

Scales.—The area of the United States (without Alaska) is about 3,025,000 square miles. On a map 240 feet long and 180 feet high the area of the United States would cover 3,025,000 square inches. Each square mile of ground surface would be represented by a corresponding square inch of map surface, and one linear mile on the ground would be represented by a linear inch on the map. This relation between distance in nature and corresponding distance on the map is called the scale of the map. In this special case it is "one mile to an inch." A map of the United States half as long and half as high would have a scale half as great; its scale would be "two miles to an inch," or four square miles to a square inch. Scale is also often expressed as a fraction, of which the numerator is a length on the map and the denominator the corresponding length in nature expressed in the same unit. Thus, as there are 63,360 inches in a mile, the scale "one mile to one inch" is expressed by $\frac{1}{63,360}$.

Three different scales are used on the atlas sheets of the U. S. Geological Survey; the smallest is $\frac{1}{250,000}$, the second $\frac{1}{125,000}$, and the largest $\frac{1}{62,500}$. These correspond approximately to four miles two miles, and one mile of natural length to one inch of map length. On the scale $\frac{1}{62,500}$ one square inch of map surface represents and corresponds nearly to one square mile; on the scale of $\frac{1}{125,000}$, to about four square miles; and on the scale of $\frac{1}{250,000}$, to about sixteen square miles. At the bottom of each atlas sheet the scale is expressed as a fraction, and it is further indicated by a "bar scale," a line divided into parts representing miles and parts of miles.

Atlas sheets.—A map of the United States on the smallest scale used by the Geological Survey would be 60 feet long and 45 feet high. If drawn on one of the larger scales it would be either two times or four times as long and high. To make it possible to use such a map it is divided into atlas sheets of convenient size which are bounded by parallels and meridians. Each sheet on the scale of $\frac{1}{250,000}$ contains one square degree (that is, represents an area one degree in extent in each direction); each sheet on the scale of $\frac{1}{125,000}$ contains one-quarter of a square degree; each sheet on the scale of $\frac{1}{62,500}$ contains one-sixteenth of a square degree These areas correspond nearly to 4000, 1000 and 250 square miles.

The atlas sheets, being only parts of one map of the United States, are laid out without regard to the boundary lines of the states, counties or townships. For convenience of reference and to suggest the district represented each sheet is given the name of some well known town or natural feature within its limits. At the sides and corners of each sheet the names of adjacent sheets are printed.

THE GEOLOGIC MAP.

A geologic map represents the distribution of rocks, and is based on a topographic map,—that is, to the topographic representation the geologic representation is added.

Rocks are of many kinds in origin, but they may be classed in four great groups: Superficial Rocks, Sedimentary Rocks, Igneous Rocks and Altered Rocks. The different kinds found within the area represented by a map are shown by devices printed in colors.

Rocks are further distinguished according to their relative ages, for rocks were not formed all at one time, but from age to age in the earth's history. The materials composing them likewise vary with locality, for the conditions of their deposition at different times and places have not been alike, and accordingly the rocks show many variations. Where beds of sand were buried beneath beds of mud, sandstone may now occur under shale; where a flow of lava cooled and was overflowed by another bed of lava, the two may be distinguished. Each of these masses is limited in extent to the area over which it was deposited, and is bounded above and below by different rocks. It is convenient in geology to call such a mass a *formation*.

(1) *Superficial rocks.*—These are composed chiefly of clay, sand and gravel, disposed in heaps and irregular beds, usually unconsolidated.

Within a recent period of the earth's history, a thick and extensive ice sheet covered the northern portion of the United States and part of British America, as one now covers Greenland. The ice gathered slowly, moved forward and retreated as glaciers do with changes of climate, and after a long and varied existence melted away. The ice left peculiar heaps and ridges of gravel; it spread layers of sand and clay, and the water flowing from it distributed sediments of various kinds far and wide. These deposits from ice and flood, together with those made by water and winds on the land and shore after the glacier had melted, and those made by similar agencies where the ice sheet did not extend, are the superficial formations. This period of the earth's history, from the beginning of the glacial epoch to the present, is called the Pleistocene period.

The distribution of the superficial rocks is shown on the map by colors printed in patterns of dots and circles.

(2) *Sedimentary rocks.*—These are conglomerate, sandstone, shale and limestone, which have been deposited beneath seas or other large bodies of water and have usually become hard.

If North America were gradually to sink a thousand feet the sea would flow over the Atlantic coast and the Mississippi and Ohio valleys from the Gulf of Mexico to the Great Lakes. The Appalachian mountains would become an archipelago in the ocean, whose shore would traverse Wisconsin, Iowa, Kansas and Texas. More extensive changes than this have repeatedly occurred in the past. The shores of the North American continent have changed from age to age, and the sea has at times covered much that is now dry land. The earth's surface is not fixed, as it seems to be; it very slowly rises or sinks over wide expanses; and as it rises or subsides the shore lines of the oceans are changed.

The bottom of the sea is made of gravel, sand and mud, which are sorted and spread. As these sediments gather they bury others already deposited and the latter harden into layers of conglomerate, sandstone, shale or limestone. When the sea bottom is raised to dry land these rocks are exposed, and then we may learn from them many facts concerning the geography of the past.

As sedimentary strata accumulate the younger beds rest on those that are older and the relative ages of the deposits may be discovered by observing their relative positions. In any series of undisturbed beds the younger bed is above the older.

Strata generally contain the remains of plants and animals which lived in the sea or were washed from the land into lakes or seas. By studying these remains or fossils it has been found that the species of each epoch of the earth's history have to a great extent differed from those of other epochs. Rocks that contain the remains of life are called *fossiliferous*. Only the simpler forms of life are found in the oldest fossiliferous rocks. From time to time more complex forms of life developed and, as the simpler ones lived on in modified forms, the kinds of living creatures on the earth multiplied. But during each epoch there lived peculiar forms, which did not exist in earlier times and have not existed since; these are *characteristic types*, and they define the age of any bed of rock in which they are found.

Beds of rock do not always occur in the positions in which they were formed. When they have been disturbed it is often difficult to determine their relative ages from their positions; then fossils are a guide to show which of two or more formations is the oldest. When two formations are remote one from the other and it is impossible to observe their relative positions, the characteristic fossil types found in them may determine which one was formed first. Fossil remains found in the rocks of different states, of different countries and of different continents afford the most important means for combining local histories into a general earth history.

Areas of sedimentary rocks are shown on the map by colors printed in patterns of parallel straight lines. To show the relative age of strata on the map, the history of the sedimentary rocks is divided into nine periods, to each of which a color is assigned. Each period is further distinguished by a letter-symbol, so that the areas may be known when the colors, on account of fading, color blindness or other cause, cannot be recognized. The names of the periods in proper order (from new to old), with the color and symbol assigned to each, are given below:

PERIOD.	SYMBOL.	COLOR—PRINTED IN PATTERNS OF PARALLEL LINES.
Neocene (youngest)	N	Yellowish buff.
Eocene	E	Olive-brown.
Cretaceous	K	Olive-green.
Juratrias	J	Gray-blue-green.
Carboniferous	C	Gray-blue.
Devonian	D	Gray-blue-purple.
Silurian	S	Gray-red-purple.
Cambrian	Є	Brown-red.
Algonkian (oldest)	A	Orange-brown.

In any district several periods may be represented, and the representation of each may include one or many formations. To distinguish the sedimentary formations of any one period from those of another, the patterns for the formations of each period are printed in the appropriate period-color; and the formations of any one period are distinguished from one another by different patterns. Two tints of the period-color are used: a pale tint (the underprint) is printed evenly over the whole surface representing the period; a dark tint (the overprint) brings out the different patterns representing formations. Each formation is furthermore given a letter-symbol, which is printed on the map with the capital letter-symbol of the period. In the case of a sedimentary formation of uncertain age the pattern is printed on white ground in the color of the period to which the formation is supposed to belong, the letter-symbol of the period being omitted.

(3) *Igneous rocks.*—These are crystalline rocks, which have cooled from a molten condition.

Deep beneath the surface, rocks are often so hot as to melt and flow into crevices, where they congeal, forming dikes and sheets. Sometimes they

DESCRIPTION OF THE FREDERICKSBURG SHEET.

GEOGRAPHY.

The provinces.—The area lying between the Atlantic Ocean and the Blue Ridge and stretching from the Hudson to Roanoke River is made up of two distinct geologic provinces. The first of these borders the ocean and is trenched by tidal estuaries; it is bounded inland by a line of rapids or cascades in the rivers, known as the "fall-line," along which the principal cities of eastern United States are located. This province is the Coastal Plain. The second province lies between the fall-line and the easternmost range of the Appalachian Mountains (the Blue Ridge in Virginia), and is known as the Piedmont Plateau.

The Coastal Plain.—While it is convenient to fix the eastern boundary of the Coastal Plain at the Atlantic shore-line, it may be more justly drawn 100 miles offshore, at the edge of the continental plateau, where the great escarpment, 3,000 to 10,000 feet high, is swept by the Gulf Stream. From the fall-line to the verge of this escarpment stretches a wonderfully smooth and even plain, inclining gently southeastward, broken only by the shallow and broad channels of the rivers and estuaries and by the line of the present shore, marked by wave-built keys and low sea-cliffs. The highest points of the province rise about 300 feet above tide; its submarine margin is about 300 feet below tide. So gentle is the inclination and so perfect the unity of the plain that if the land were elevated or depressed 100 or 200 feet the shore-line would simply be shifted about as many miles. Thus the position of the coast may be considered an accident of the present slope and altitude of the land—indeed, between the mouth of the Hudson and Chesapeake Bay the present coast does not coincide with the trend of the province but cuts obliquely across half its width, so that, while only about half the province is submerged in the latitude of Richmond, it is nearly all beneath tide in the latitude of New York.

Below tide-level the province is an even and nearly level sea-bottom; above tide-level it is a lowland of broad, flat terraces, which skirt the coast and the estuaries, sometimes rising into gently undulating plains toward the low divides. The principal waterways are broad yet shallow estuaries, flanked sometimes by tidal marshes, sometimes by low sea-cliffs; the lesser waterways are commonly estuarine in their lower reaches, but narrow and steep-bluffed in the upper reaches, frequently heading in narrow ravines cut sharply into the extensive plains of the divides.

The Piedmont Plateau.—This province is an undulating plain inclining eastward and southeastward from altitudes of 700 to 1,500 feet along the Blue Ridge to altitudes ranging from 200 to 400 feet along the fall-line. The plain is here and there relieved by bosses or ridges, generally trending in the direction of its length, and it is trenched by channels cut directly across it. The elevations mark outcrops of exceptionally hard rocks. The valley of the Rappahannock is a good example of the transverse trenches. About the heads of smaller streams, but apart from the knobs or ridges, the surface is a succession of rounded hills along the divides, while the hills are lower and the ravines deeper and narrower toward the larger streams. Followed up stream, the primary waterways divide into secondary streams, these into smaller brooks, and these again into minor ravines which break up and ramify over the entire surface so widely that every part is completely drained, neither lake nor swamp being found in the province unless produced artificially. Between the minor ravines the land rises in swelling slopes; and the ravines and the valleys of brooks, secondary streams, and primary waterways are narrow, so that the common profiles drawn along lines in any direction are chiefly broad, convex curves, separated by narrow notches in which the curvature is usually concave.

Throughout the inland two-thirds of the plateau the waterways—and therefore the valleys and hills—are determined by inequalities in the hardness of the rocks; i. e., the valleys mark the position of softer or more soluble rocks, the divides those of harder or less soluble rocks. Over the seaward third of the plateau this relation frequently fails, the stream courses often cutting across hard and soft rocks alike; and in this zone the hills are sometimes crowned with remnants of gravelly deposits, as at Mount View and elsewhere in the vicinity of Fredericksburg.

The fall-line.—North of the Rappahannock the rivers traversing the Piedmont Plateau cascade over rocky ledges directly into arms of the ocean, and are transformed at once from narrow and shallow, unnavigable torrents into tidal estuaries. Generally north of the Potomac, and everywhere north of the Susquehanna, the inland margin of the Coastal Plain inclines landward, forming a broad though shallow trough, occupied largely by tidal waters. So deep and continuous is this trough that the land portion of the Coastal Plain is converted into a series of peninsulas, connected with the mainland by narrow and generally low isthmuses. Measured along the fall-line, the Hudson is barred from the Rappahannock, 300 miles southward, by but 60 miles of land and non-tidal water. The Rappahannock, the James, the Appomattox, and the Roanoke, like the more northerly Piedmont rivers, cascade over rocky ledges into the province of the Coastal Plain, descending at once to tide-level; but the tidal reaches are relatively narrow canals, instead of broad estuaries as in the north, while the marginal trough is lacking. Still farther southward the Piedmont rivers are rapid and tumultuous on passing into the Coastal Plain, but the natural canals forming their lower reaches are tidal for only part of their length, though the waters are commonly slack and navigable nearly or quite to the falls.

By reason of these features the inland margin of the Coastal Plain is a strongly marked geologic boundary; and few other natural lines in the world have so profoundly affected people and industries. The estuaries afford navigable channels and harbors, and the falls of the rivers give water power. The pioneer settlers of the country ascended the slack-water channels to the falls at their heads, where they found, sometimes within a mile, safe anchorage, fresh water, the game of the hills and woodlands, and the fish and fowl of the estuaries. Here the early settlements and towns were located, and as the population increased, the abundant water power and excellent mill sites, the easy ferriages and natural bridge foundations, were utilized. Towns grew apace, and across the low isthmuses the pioneer routes of travel were extended from settlement to settlement and from town to town until the entire fall-line was converted into a great social and commercial artery, stretching from New England to the Gulf States. As population grew and spread, the settlements and towns along this natural boundary waxed, and many of them yet retain their early prestige. Trenton, Philadelphia, Wilmington, Port Deposit, Baltimore, Bladensburg, Washington, Alexandria, Dumfries, Fredericksburg, Richmond, and Petersburg are among the survivors of the pioneer settlements, and the hunter's trail and more advanced stage route of primitive times has become a great railway and telegraph line, rivaling the open ocean as a highway for commerce and intelligence.

TOPOGRAPHY.

The Fredericksburg area.—The area included in the Fredericksburg sheet is one-quarter of a square degree, bounded by the parallels 38° and 38° 30′ and the meridians 77° and 77° 30′. It measures approximately 34.5 miles from north to south and 27.3 miles from east to west, and embraces about 938 square miles. The area lies chiefly in Virginia, but its northeastern corner extends a little way into Maryland. In Virginia it comprises King George County, with parts of Caroline, Stafford, Essex, Westmoreland, and Spottsylvania, and in Maryland it includes the southwestern part of Charles County.

Topographic types.—In addition to the water area (chiefly the Potomac estuary), the tract is characterized by three distinct types of topography: (1) that of the Piedmont Plateau, with its bordering fall-line; (2) that of the more elevated portions of the Coastal Plain; and (3) that of the lowlands flanking the waterways.

The topography of the Piedmont type is confined to the northwestern corner of the tract. Here the waterways are narrow, steep-bluffed gorges, and the valley sides rise with diminishing slope toward the divides; and the divides are round-topped ridges wandering sinuously between the main streams and sending off round-topped, meandering spurs and branches between each pair of tributaries. Thus the surface rises in convex slopes and curves from V-shape ravines unto rolling uplands; the altitude at each point is proportionate to the distance from water-courses, and there are no tabular divides or ill-drained expanses.

The second topographic type is that of those portions of the Coastal Plain lying between the broad valleys of the principal rivers. Here all the streams, except the smaller headwater brooklets and rivulets, wander sluggishly through broad flood-plains of their own alluvium. The alluvium belts are flanked by moderately steep but low slopes, rising into broad, tabular, and frequently ill-drained expanses, which here replace the rounded divides of the Piedmont type, into which they merge at the higher levels. The brooklets and rivulets occupy V-shape ravines like those of the neighboring province; but they are short, and commonly head abruptly about the broad interstream plains in such fashion as to scallop the margins, leaving the interiors without water-courses sometimes for miles, as in the case of the divide northeast of Bowling Green. There is thus little relation between the altitude of a given point and the proximity of waterways; and over much of the area of this type the waters do not gather in a uniform way on accordant slopes, but either run rapidly down the narrow ravines of the brooklets or soak into the earth to find their way slowly seaward as ground water.

The third type of topography appears in the broad terraces flanking Potomac, Rappahannock, and Mattapony rivers. These terraces are akin to the higher interstream plains, but the streamways are much shallower, by reason of the lesser altitude above tide, as well as less frequent, so that nearly all of this type of area consists of monotonous, ill-drained lowland, which near the ocean merges into tidal marshes.

The characteristics of the three types of topography are clearly indicated by the topographic map, albeit in some measure they intergrade. Along the divides the Piedmont Plateau grades into the Coastal Plain so insensibly that the tract appears a fairly uniform plain, inclining gently southeastward and gradually flattening with descent; but in the valleys the transition is sharp. So, too, the broad interstream divides of the Coastal Plain may grade into the terraces of the river sides, particularly along brooks of medium size, and indeed, these divides themselves consist of terraces, only higher, broader, and better drained than those skirting the rivers; but on the minor divides between the brooks and along the main waterways the interstream plains overlook the river terraces in definite escarpments, and these escarpments are accentuated by difference in geologic age of the lower and higher plains.

The topographic history.—Classifying the topography by origin, it is found to yield a record of geologic and geographic history. All the topographic forms are the result of sculpture by storms and streams, and the character of sculpture in different portions of the tract depends upon the degree of completeness of the work now accomplished. Throughout the Coastal Plain the carving has affected only a portion of the surface of the ancient terraces, while in the Piedmont upland the entire surface is harmoniously incised; and the sculpturing of the riverside terraces is much less advanced than that of the higher interstream divides. Thus the three topographic types represent different stages of progress in the sculpture of the land by falling and running waters; and the slightly modified terraces of the river sides and the largely modified interstream terraces still retain the original configuration of the tract as it gradually rose from the sea and was thereby transformed from ocean-bed to lowland. This record of topographic development is consistent with the geologic record found in the deposits of the Coastal Plain.

The headwater brooklets of the low interstream divides in the Coastal Plain gather in steep-sided ravines, which they are rapidly deepening and carrying backward farther and farther into the tabular divides; and in time of storm they are transformed into torrents and transport seaward great quantities of the débris of the land. Yet the same streams in the lower courses and the principal rivers of the tract are not deepening their channels, but are filling their valleys with the flood-borne débris; for they lie at or near the level of the ocean. Moreover, the lower reaches of the streamways are broad plains built up of just such deposits as those brought down in the freshets, and these deposits overlap the edges and rise against the scarps of the interstream plains. This topographic record combines with the record of geology in the Coastal Plain and tells that the lowland, which was lifted from the sea-bottom, is again subsiding and that the sea is encroaching on the land in its estuaries, even unto the margin of the Piedmont Plateau at the fall-line.

Along the Piedmont margin the principal rivers and many smaller streams descend from the plateau to the lowland in cascades and rapids; and these falls lie within narrow, sharp-cut gorges, in which the angular contours and fresh rock surfaces indicate recent cutting, or what may be called topographic youth. A good example of these gorges is afforded by the Rappahannock in its rapids and cascades at and above Falmouth. Other examples are found in Potomac and Aquia creeks, which exhibit corresponding rocky gorges constantly subjected to scouring by the sand-laden waters. These gorges and cascades or rapids indicate an elevation of the Piedmont tract; and this record of land movement is in harmony with the record found in the deposits of the Coastal Plain.

The youthful gorge of the Rappahannock is cut in the bottom of a larger, wider, and longer gorge, extending well toward the headwaters of this stream and its principal tributaries; and in Potomac and Aquia creeks and rugged gorges of the fall-line are cut a little way into the bottoms of broader canyons extending some miles inland. These greater gorges are from 100 to over 200 feet in depth and usually a quarter of a mile to a mile in width. Their sides are steep bluffs, often precipitous, rising toward the undulating plane of the plateau, and their bottoms are the flood-plains of the rivers. Traced into the Coastal Plain, the flat bottoms of the greater gorges are found to coincide with the broad terraces of the river sides exemplifying the third type of topography, while the narrow gorges of the cascades are the extension of the alluvium-lined channels of the larger streams. The relative absence of fresh rock surfaces and the soft contours indicate that the greater gorges, especially within the Piedmont province, are much older than the lesser gorges occupied by the cascades. Together they indicate that during a relatively remote period the Piedmont Plateau was lifted considerably above its present altitude and at the same time tilted seaward, and that this altitude and attitude persisted long enough to permit the streams gradually to deepen and widen their ways. This period of high level in the plateau has been correlated with a period of nearly coeval deposits (the Lafayette) in the Coastal Plain.

Viewed in the light of the history recorded by the gorges, the general topography of the seaward margin of the Piedmont Plateau becomes significant: it indicates that for a long period before the cutting of the greater gorges the land stood so low that the streams flowed sluggishly and carried little detritus toward the sea; in other words, it indicates that the general surface was reduced to baselevel (the level at which streams cease to scour their channels), and that this condition persisted for a vast period. During this period the land rose and sank more than once, though these minor oscillations are not clearly expressed in the topography; but the baselevel period has been correlated with certain deposits

and unconformities of the Coastal Plain, and there the lesser oscillations are recorded in fuller detail.

Thus the topographic types and forms of the tract yield a record of history, and this record supplements and corroborates the record found in the deposits.

GEOLOGY.

THE ROCKS AND THEIR RELATIONS.

The geologic formations of the Fredericksburg area are of two classes: those of the Coastal Plain, comprising clays, sands, loams, marls, diatomaceous earths, and marshy accumulations; and those of the Piedmont Plateau, comprising gneisses, granites, slates, etc. The formations of the Coastal Plain belong to four extensive sheets, lying one over another and dipping gently eastward, partly overlain by a fifth deposit, which is thinly spread over the lower areas along the rivers and estuaries, generally in the form of terraces. All of these formations overlie the irregular surface of the Piedmont mass, which is of great but unmeasured thickness. The lower three formations of the Coastal Plain thicken eastward, and on the west abut against the slopes of the crystalline rocks; the fourth sheet overlaps them and extends westward for some distance over the crystallines; while the fifth deposit rests on the crystallines only in the deeper valleys.

Classified by origin, the geologic formations of the Coastal Plain consist chiefly of little-altered sediments, while the Piedmont rocks are much-altered ancient sediments and igneous masses. The Coastal Plain sediments may somewhat arbitrarily be subdivided into two categories, the first corresponding more or less closely to those now in process of deposition in the estuaries and along the shores in the immediate vicinity; the second corresponding closely to offshore sediments known from soundings and samples to be in process of deposition over the more deeply submerged portions of the province. In general, the deposits of the first category overlie, and are thus known to be younger than, those of the second category. The younger formations record certain modifications in geography due to changes in altitude of the land, and, moreover, display certain distinctive characteristics indicating the climate of the periods during which they were laid down. The next older formations contain abundant remains of marine organisms, preserved as fossils, and thus these deposits are records of periods during which the land stood lower and the sea consequently pushed farther inland than at present. The lowest and oldest formation of the Coastal Plain series is nearly devoid of marine fossils, but its beds contain impressions of leaves, together with lignitized wood and other vegetal fossils, as well as the bones and teeth of dinosaurs. In addition, the deposits are coarse and irregularly bedded; so that this formation, like the younger deposits, appears to be a record of shores, and thus of an altitude of the land not greatly different from that of the present. The formations range in age from late Pleistocene or Recent to early Cretaceous. The successive formations are separated by unconformities, each representing a period during which the land stood higher than at present, and during which the surface was sculptured by storms and streams, so that when the succeeding deposit was laid down its strata were more or less discordant with the partially eroded strata of the preceding period.

The rocks of the portion of the Piedmont Plateau within and adjacent to the area represented on the Fredericksburg sheet are crystalline schists or gneisses with associated granites and slates. The rocks are highly tilted, and in general profoundly metamorphosed; and along the fall-line they are overlain with strong unconformity by the Coastal Plain deposits. The Piedmont gneisses and their associates are intersected by veins of quartz; and this, with some other materials, establishes a connection between the adjacent provinces. During those periods when the land stood low the Piedmont rivers were sluggish and the materials carried into the sea were chiefly products of chemical action, but the rocks were deeply decomposed, so that the obdurate quartz projected as ledges in valleys and ridges over the upland; when the land rose the rivers were stimulated and the residua of decomposition, together with the quartz fragments gathered by the streams, were carried down to form the littoral deposits of the plain. Thus it is known that the deposits of the lowland province are derived from the rocks of the neighboring upland province; and through extension of the interpretation it is known also that the sedimentary deposits of the younger province correspond to the valleys and ravines of the older one, so that the Coastal formations and the Piedmont land-forms are related in a reciprocal way.

The formations and unconformities in the Fredericksburg area are shown in the following table:

Period.	Formation.	Character.	Thickness in Feet.
Recent	Alluvium.	River mud, talus, marsh, etc.	0-30
	Unconformity.		
Pleistocene	Columbia.	Loams, sands, and gravels.	0-30
	Great unconformity.		
Neocene	Lafayette.	Gravelly orange sands and loams.	15-30
	Unconformity.		
	Chesapeake.	Fine sands, clays, and diatomaceous deposits.	1-180
	Unconformity.		
Eocene	Pamunkey.	Dark glauconitic sands and marls.	10-300
	Great unconformity.		
Cretaceous	Potomac.	Sands, sandstones, clays, and gravels.	5-300
	Very great unconformity.		
Pre-Cambrian?	Piedmont (>Quantico).	Gneisses and other metamorphic rocks.	Unknown.

ALLUVIUM.

Commonly alluvium is deposited by rivers in the form of deltas and flood-plains, which rise above the level of tide; but in the Fredericksburg area the alluvium is mainly laid down below the level of tide, forming a surface deposit only on freshet plains and in the valleys of small streams, where its presence is relatively transient. Accordingly, this deposit is not represented on the map.

The practical absence of alluvium within the Coastal Plain in the Fredericksburg area is due to the subsidence of this province, now in progress at a rate more rapid than that of alluviation; its absence in the Piedmont province is due to the elevation of the land, now in progress at a rate so rapid as to outrun the vertical cutting of the streams, so that the products of corrasion are carried away.

Marsh growth has kept pace with subsidence in a number of localities along Rappahannock River and along the several smaller streams tributary to the Potomac within the Coastal Plain province. These marshes are for the most part tidal, and represent the joint operation of sedimentation and vegetal growth. In the valley of the Mattapony there is considerable fresh-water marsh, due to the gradual slackening of flow with the subsidence of the land. In these marshy areas the vegetal accumulations are mixed with sand and clay deposited during the freshets. The fresh-water marshes are susceptible of modification or reclamation by artificial drainage or by natural changes in the watercourses, and may therefore be regarded as temporary. Within limits the tidal marshes are also subject to modification by natural or artificial changes in drainage.

It may be noted that while the marsh lands are measurably susceptible of artificial control, the area in which they occur is affected by the slow subsidence of the Coastal Plain, so that the natural tendency is toward the drowning of estuaries and thus toward increase of the marsh area.

THE COLUMBIA FORMATION.

One of the more extensive geologic formations of the Fredericksburg area is a deposit of loam and gravel or bowlders along the waterways and extending for some distance up the tributary valleys toward the lower divides. Along the rivers the deposit is fairly uniform, consisting of a bed of loam (i. e., sand and clay mixed in various proportions) 5 to 20 feet thick, grading downward into a bed of bowlders, gravel, or sand, or all combined, from 3 to 10 feet thick, the loam being commonly unstratified, and the coarser members stratified and cross-bedded. This is the fluvial phase of the formation. Toward the lower divides the deposit is reduced to an irregular bed of wave-washed and rearranged materials, composed in part of débris derived from the underlying formations in the immediate vicinity, in part of débris transported from greater distances by streams or currents; this being the interfluvial phase of the formation, which is not well developed in the Fredericksburg area. The two phases are combined under the name Columbia formation, so called from the District of Columbia, in which the deposits are typically exposed.

Within the Fredericksburg area the materials of the Columbia formation are somewhat variable. In the largest continuous body, about the great loop of Potomac River, in the northern part of the tract, they conform closely to the type of the formation. Here the upper portion consists of a fairly homogenous bed of loam, while the lower portion is stratified and contains coarser materials, together with layers of silt (exceedingly fine sand). West of Potomac River, on Aquia, Accakeek, and Potomac creeks, the lower member is coarser, frequently containing pebbles and even large bowlders such as are found in corresponding portions in the type area. The prevailing color of the deposit is brown or drab, and is determined by the presence of ferric oxide. The coloring of the more heterogeneous lower member is somewhat variable, the sands sometimes assuming dark-brown or brick-red tints when partially or wholly cemented by ferruginous infiltration, and again bleaching nearly white; while the silt layers are commonly ash-colored or whitish, and weather out in pinnacles, giving a peculiar dentate or serrate character to the cliffs. Occasionally black or blue-black bands and patches appear, especially in the coarser beds. In these the coloring matter is protoxide of iron, sometimes (perhaps always) associated with cobalt. The stain or cement coats the pebbles and sand grains externally, but seldom permeates any but the smaller particles.

In the Rappahannock Valley the loam member is hardly so thick as along the Potomac, while the basal member is quite coarse toward the fall-line, containing numerous cobbles and bowlders up to 2 feet in diameter in the vicinity of Fredericksburg, though the materials diminish in coarseness downstream, until toward the eastern margin of the area the basal deposits consist chiefly of sand and gravel, as along the Potomac. About Fredericksburg the basal member comprises angular or waterworn fragments of quartz, gneiss, etc., imbedded in coarse sand, and this member merges upward into the usual brown loam with sandy and gravelly layers. In the Mattapony Valley the exposures of the Columbia formation are seldom clear, but enough have been observed to indicate that the deposit consists mainly of moderately fine sand, with more or less continuous gravel beds at the base, becoming loamy, yet with occasional layers of small pebbles, above; the average thickness being about 20 feet.

On the whole the materials of the Columbia deposits conform in considerable measure with those transported by the rivers of the same region during freshets; and the distribution of the materials—the coarser below and near the fall-line, the finer above and further downstream—is similar to that of freshet work. The materials differ from those laid down during ordinary freshets, (1) in greater coarseness and (2) in containing a larger proportion of completely disintegrated and chemically stable rock matter in the upper member. These features are indicative of climatic conditions during the period of deposition of the formation; they point to colder climate, when the ice froze thicker than now and carried larger bowlders than those transported in the modern ice-floes, and when, moreover, the snowfall was greater than now, so that the spring freshets collected and transported seaward a larger quantity of residuary clays and loams of the Piedmont province than they now transport.

The Columbia formation occurs chiefly in broad terraces skirting the main waterways and reaching altitudes ranging from 5 to 70 feet above tide. Originally the deposit floored the broader valleys from side to side, but the rivers have cut channels into and sometimes through it, and some of the smaller streams have cleared the greater portion of the material from their valleys. In the vicinity of Fredericksburg the terraces commonly overlook the river in rounded scarps; but along the Potomac and in part along the lower Rappahannock the tidal waters have sapped the scarps, and the formation rises in steep banks or talus-free precipices from the water's edge. About Riverside Landing and at the mouth of Mallows Creek, as well as in some other localities, the banks are 20 feet high, and give clear exposures of the formation. The precipitous cliffs of this deposit constitute one of several indications of the subsidence of the land; for it is known through observation in many districts that the encroaching waters of subsiding shores bear away into the depths materials that ordinarily accumulate as talus. The terrace surfaces are broad, nearly level expanses which, if sufficiently elevated to be well drained, form fertile fields. Although somewhat variable in altitude, these terraces meander the main valleys and extend into tributaries in such manner as to outline the geography when the land was so depressed as to submerge a considerable part of the Coastal Plain, and the distribution of the formation is at once a record and a measure of the subsidence. From this record it appears that the Columbia waters did not at any time rise much higher in this tract than when the broad terraces were formed, so that the interfluvial phase of the formation is not well developed.

Although the Columbia formation occupies less than half of that portion of the Coastal Plain in the Fredericksburg area, it is one of the most extensive in the province; it covers a great part of the surface of the coastward lowland in the middle Atlantic slope, and doubtless lines portions of the estuaries and floors the ocean-bottom far out to sea, though it is thin over the higher lands and its thicker portions are partly or wholly submerged. Elsewhere the fluvial and interfluvial phases are sometimes distinct; and moreover, the formation sometimes exhibits well-marked chronologic phases, to which distinctive designations have been given; but these phases are not clearly displayed in the Fredericksburg area.

THE LAFAYETTE FORMATION.

The most extensive formation shown on the Fredericksburg map is a thin but quite uniform deposit of well-rounded gravel imbedded in a matrix of red or orange-tinted loam, called the Lafayette formation, from the county of that name in Mississippi in which it is typically displayed. The tabular divides between the Potomac and the Rappahannock and between the latter river and the Mattapony, as well as the broader interstream plains elsewhere, are formed of this deposit; and isolated patches of the same deposit occur over the crystalline rocks of the Piedmont province some miles inland of the fall-line. The surface of the formation, like the general surface of the Fredericksburg area, of which it forms a large part, inclines gently eastward from an altitude of about 325 feet at Mountain View to about 175 feet in the neighborhood of Bethlehem Fork.

The materials of the formation are quite uniform in character, consisting of sandy loams of orange, brown, and buff tints, containing irregularly disposed bands and beds of pebbles and coarse sand. The pebbles and larger sand grains are orange tinted, though the stain is largely superficial. Some portions of the loam are clayey, and these portions are sometimes light-colored, buff, pink, or cream tints being the most frequent. The coloration of the deposit is due to ferric oxide, and sometimes the sands and gravels are incrusted or cemented in layers and masses by iron oxides. Local variations in the composition of the formation occur irregularly, but in general the materials increase in coarseness westward, particularly in the lower beds. In the eastern part of the area the basal layers consist largely of fine sands, evidently derived mainly from the Chesapeake formation, intercalated with layers of coarser sands; the upper portion of the formation being often a gray or buff loam, with layers of fine gravel. Sometimes these layers are weathered or washed out to form the tabular surface of the broad, low divides in Caroline, Essex, and King George counties. Toward the fall-line in Stafford and Spottsylvania counties the orange color is more predominant, and sandy and gravelly beds prevail; and about Summit, as well as in the outlier at Mountain View, the deposit consists largely of marble-size and egg-size pebbles, chiefly of quartz, closely packed in a tough, orange, sandy loam. In Charles County, Maryland, the formation consists mainly of sandy, orange loams, with scattered pebbles and pebble beds. The pebbles are in general thoroughly waterworn and well-rounded. They were evidently derived originally, in large part, from the vein quartz of the Piedmont province; but there are indications that many of them had an intermediate history as constituents of the Potomac formation.

The formation averages from 15 to 20 feet in thickness, though locally it is slightly in excess of the latter figure. Toward the waterways it commonly terminates in abrupt scarps, but along the western margin it thins out in feather edges. In some districts the formation thins toward the

divides, but in the Fredericksburg area this feature is inconspicuous or absent, though in addition to the eastward slope the surface of the deposit inclines slightly toward the Potomac, Rappahannock, and Mattapony valleys. It rests unconformably on all of the older formations of the area; and where in contact with the Columbia formation the latter overlaps its margin.

From the composition and distribution of the materials it is evident that the formation was originally deposited as a continuous mantle over this portion of the Coastal Plain and extended some distance upon the seaward border of the Piedmont Plateau, and also that the materials were carried down by the rivers and lesser streams and distributed and assorted over the Coastal Plain area by the action of waves and currents. The materials differ from those deposited by the modern streams chiefly in the more abundant elements of quartz and thoroughly leached loamy matter corresponding with the residuary clays of the Piedmont. From its characteristics of composition and structure it is known to be a littoral formation, deposited when the land, after standing a long time at or near baselevel, was partly submerged and at the same time tilted seaward, so that the streams were stimulated and enabled to transport seaward the chemically stable quartz and residuary products in exceptional quantity.

The originally continuous mantle apparently undulated slightly, inclining toward the larger valleys, which are thus known to antedate the formation in something like their present geography; and along these valleys the mantle has since been invaded by erosion, cut entirely through, and the greater part of the volume carried away; so that the existing areas are but remnants of a once continuous sheet whose extent and continuity vary inversely with the proximity and size of the streams. The post-Lafayette erosion did not cease with the dissection of the Lafayette mantle, but extended far into the underlying formations; and while the valley profiles beneath the Columbia formation are not thoroughly known in the Fredericksburg area, enough is known of the configuration here and elsewhere to indicate that the pre-Lafayette valleys were greatly deepened after the formation was laid down. Moreover, the configuration of the pre-Columbia surface indicates not only that the land stood higher than now above the sea during the post-Lafayette period, but that this period of high level was too short to permit the complete reduction of the surface to baselevel. Thus the presence of the Lafayette formation is a record of submergence, involving the entire Coastal Plain in the Fredericksburg area and extending also some distance into the Piedmont province, while the partial erosion of the deposit is a record of a relatively brief high-level period, during which the land stood much higher than now. Thus the unconformity between the Lafayette and Columbia formations, which is one of the most notable within the area, is found to be especially significant in its bearing on the geologic history of the region.

South of the Fredericksburg area the Lafayette formation increases in extent, until in coastal North Carolina it is a nearly continuous mantle; and still farther southward and southwestward it expands in width and increases in thickness, notably in the Mississippi embayment. North of Potomac River the formation is known only in remnants, which grow successively smaller and smaller through Maryland and Delaware and into the peninsula of New Jersey, where only scattered outliers are found within the Delaware drainage basin, though the deposit is much more continuous over the Atlantic drainage area. The Lafayette formation is perhaps the most extensive in area and the most uniform in character in the United States.

THE CHESAPEAKE FORMATION.

In the Fredericksburg area the Lafayette formation rests unconformably on a bed of marine deposits which has been named after Chesapeake Bay, on the shores of which it is typically displayed. These deposits occupy all the higher portion of the area east and southeast of Fredericksburg, as well as that adjoining Port Tobacco River in Maryland. Their base passes beneath tide-level near the western limits of Westmoreland and Essex counties, and they appear to underlie the upper Mattapony valley. The formation is concealed by the Lafayette mantle over the low uplands of the Coastal Plain in the vicinity of Fredericksburg; it crops out toward the base of the Lafayette scarp over the southeastern two-thirds of the area mapped, and in the southeastern half it is terraced and overlain by the Columbia deposits. As its altitude increases northeastward it is more and more extensively eroded, and in western King George County and southeastern Stafford County it attenuates and ends in a series of outliers on the higher ridges south of Potomac Creek. South of Fredericksburg the margin of the formation appears in the ravines about the head of Deep Run; farther southwestward it is not found as a surface deposit, the Lafayette formation directly overlapping the Pamunkey. On the Maryland side of the Potomac the formation occupies the high ridges adjacent to Port Tobacco River, extending southeastward along the northern bank of the Potomac estuary.

The materials of the Chespeake formation are mainly fine sands intermixed or intercalated with clays, accumulations of minute shells of diatoms or infusoria forming infusorial earths, and glauconite or greensand, locally known as marl. The sands commonly contain more or less clay, and when wet and freshly exposed are hard and tough, and dark-gray or dark-olive in color; on weathering, the beds usually assume a light-gray color, though in some localities they are stained buff, probably in part at least by ferruginous solutions from the overlying Lafayette beds. The weathered material is friable, with a peculiarly meal-like appearance and texture.

In the eastern portion of the Fredericksburg area the mealy sands of the Chesapeake grade downward into diatomaceous beds, often consisting mainly of diatom remains, with only a small admixture of clay and fine sand. The diatomaceous beds form a characteristic horizon traversing a belt 5 or 6 miles wide, which crosses Potomac River a little way below the mouth of the Port Tobacco, follows the western side of Westmoreland County, and crosses Rappahannock River into Essex County about Elmwood Creek. The finest exposures are in the high cliffs on the northeastern side of the Rappahannock 5 miles above Leedstown, and in the bluffs of Port Tobacco and Potomac rivers in the neighborhood of Chapel Point. Farther westward the beds are less perfectly exposed in ravines and scarps. The westernmost exposure in the Rappannock Valley is in the river bluffs 5 miles above Port Royal, where the diatom remains are intermixed in varying proportions with fine sands and clays, though they sometimes predominate and constitute nearly pure layers of considerable thickness. The diatomaceous deposit is light-colored, often snow-white or slightly tinted with buff or gray; and when pure, or nearly so, it is of very low specific gravity, so that when dry it readily floats on water, though when saturated it is heavy, tough, and dark-gray or pale-olive in color.

In Caroline County the sands of the Chesapeake become argillaceous, and there are many beds of gray and bluish clays. These contain layers of fossiliferous glauconite (or shell marl) of varying dimensions and degrees of purity, which are conspicuous about Bowling Green. Freshly exposed, these marls are light-gray, and often contain a large proportion of fossil shells; but after long exposure near the surface they weather to buff argillaceous sands, with casts and impressions of fossils, the shells being leached away. The most extensive exposures of clays are in the railway cuts about Summit, though in that vicinity the marls are not well developed. The clayey and marly members are higher in the formation than the diatomaceous deposits, but appear to merge into them.

The greatest thickness of the Chesapeake formation in the Fredericksburg area is in Essex County, where it reaches 180 feet. It thins westward, mainly by the attenuation or dropping out of the basal members, and finally ends in a feather edge, overlapped by the Lafayette deposits. The basal beds are usually darker for a few inches or feet, and contain small black quartz pebbles, especially at the contact with the Pamunkey formation. Throughout most of the Fredericksburg area the Chesapeake rests on the Pamunkey, but in Caroline and Spottsylvania counties the clay and marl series overlap on the crystalline rocks of the Piedmont. Exposures of the contact between the Chesapeake and the ancient crystallines are rare, though several exist in the valleys of South, Matta, Po, and Ny rivers.

Fossils occur in greater or less abundance throughout the formation. In the marly beds they are mainly shells, and elsewhere chiefly casts and impressions of shells which have leached away. Fossil bones frequently occur in the lower beds of the formation, and more or less complete skeletons of large cetacea have been found. The diatomaceous or infusorial deposits are beds made up of the fossil shells of a great variety of minute organisms, which are beautifully distinct under a moderately powerful microscope. The age of the formation, as indicated by the fossils, is early Neocene (Miocene), though in this region representatives of the earliest Neocene and of the later (pre-Lafayette) Neocene are lacking.

The Chesapeake formation lies on a relatively smooth surface, chiefly that of the Pamunkey formation, which in the western part of the area becomes more irregular, particularly where composed of the Piedmont crystallines. This surface inclines southeastward about 10 feet per mile north of Rappahannock River, and somewhat less farther southward. The sub-Chesapeake surface is at tide-water along a line crossing Potomac River near the mouth of Machodoc Creek, and crossing the Rappahannock 6 miles below Port Royal; it rises to an altitude of 220 feet in the high plain 4 miles northeast of Fredericksburg, from which point it inclines southwestward to about 100 feet to Massaponax Creek and 80 feet around Bowling Green. In Charles County it inclines from a maximum altitude of 90 feet to about 65 feet. The Chesapeake-Pamunkey contact is frequently exposed along Rappahannock River and in road-cuts near the lateral branches of that stream. It also appears high up in the slopes between Potomac Creek and Mathias Point, as well as throughout the Chesapeake area in Charles County, Maryland.

The Chesapeake formation is a typical offshore marine deposit; the fossils are remains of organisms such as inhabit relatively shallow sea waters some miles or scores of miles offshore; the sands and clays are such as are supplied by rivers of moderate declivity, though assorted and deposited as by waves and littoral currents; the diatoms are such as live in relatively shallow and quiet waters in temperate and subtropical zones; the glauconitic deposits are such as are produced by the action of certain minute organisms subsisting in sea waters on feldspathic and other constituents of crystalline rocks. Thus the deposit is a record of the geographic conditions attending its deposition; while the slightly discordant unconformities by which it is bounded indicate that the oscillations of the land by which the period of its deposition was preceded, introduced, and terminated, were of small amplitude.

In the Fredericksburg area the Chesapeake formation is a unit, and the sole representative of the earlier Neocene; but both in the northern and southern portions of the Coastal Plain province other deposits representing the period come in above and below this well-defined member of the geologic series.

THE PAMUNKEY FORMATION.

Nearly all of the Fredericksburg area is underlain by a fairly homogeneous sheet of sand and clay, with occasional limy layers and glauconitic beds, although throughout most of its extent it is overlain by the Columbia, Lafayette, and Chesapeake formations. This has been named the Pamunkey formation from Pamunkey River, Virginia. It is exposed beneath the Chesapeake in the scarps of the Lafayette plateaus northwest of a line passing a little way below Port Royal and Mathias Point; northeast of Fredericksburg it forms the surface over considerable areas; and it terminates northwestward in a series of outliers, capping the higher ridges of the Potomac sandstone. Along Rappahannock River there are many outcrops in the bluffs, notably in those extending from Port Royal westward. Good exposures occur also in the banks of Potomac River from the mouth of Aquia Creek to Mathias Point, as well as on the western side of Aquia Creek and along the railway thence to Potomac Creek. The finest exposures in the Fredericksburg area are in the great bluffs just below the mouth of Aquia and Potomac creeks, at Clifton Beach, and in the railway cuts north of Brooke. In the Mattapony valley there are several clear outcrops along the river banks below Milford, notably below the railway bridge 3 miles south of this town. On the Maryland side of the Potomac the formation is well exposed along Port Tobacco River and in the bluffs below its mouth.

The materials of the formation are mainly glauconitic sands and marls, which in their fresh and moist condition are dark-green or black. They often contain large numbers of shells, with more or less calcareous material. On weathering they become lighter in color, the shells and other calcareous elements are removed by solution, and the resulting material is a buff sand containing more or less redeposited iron in brown streaks or blotches or in limonitic crusts. In the partially weathered material, such as commonly appears in exposures, there are streaks of brown and buff carrying greenish grains. The weathered and partially weathered phases of the formation are conspicuous in the outliers as well as in the main body in Stafford County, where the Lafayette and Chesapeake mantles, which afford protection farther southward, were long ago removed. In part of Charles County there is in the upper part of the formation a bed of light-pink or pinkish-buff clay. This is well exposed about the first summit south of Potomac Creek, on the road from Brooke to Fredericksburg; its thickness is 12 feet, and it is overlain by Lafayette loams and gravels. This clay is exposed also at many points in the ridge between Accakeek and Aquia creeks; and in the high cliffs on Potomac River, just below the mouth of Aquia Creek, the clay is nearly white, 4 feet thick, and 80 feet above the water, overlain by 15 feet of weathered glauconitic sands containing casts of Eocene fossils. Below the clays at this point there are sands containing considerable glauconite, and these grade down into highly glauconitic sands, carrying many shells, shark teeth, and fragments of bone; while near the base of the cliff there are layers of rock consisting of silicified sands, and these are filled with remains of the screw-like shells of *Turritella mortoni*. These rock layers average 3 feet in thickness, and extend as a fairly regular stratum (though of varying depth) nearly to the extremity of Marlboro Point. A similar hard bed, with the same fossils, was observed in the Rappahannock valley near Moss Neck post-office. A short distance east of Stafford Court House, on the road to Brooke, there is a local development of siliceous beds, which occupies several acres and attains a thickness of 8 feet. Here the rock is quite hard, and contains a variety of fossils.

At the base of the Pamunkey formation there is usually a bed of gravel and bowlders, or gravelly green and gray sands, 1 foot to 2 feet in thickness, lying on the surface of the Potomac formation, and consisting largely of Potomac débris. The basal bed of the Pamunkey and the contact with the Potomac formation are frequently exposed in Stafford County, as north of Fredericksburg, just north of Falmouth, about Brooke, near Stafford Court House, and in many other localities; south of Fredericksburg they may be seen on Hazel Run and the Massaponax. In some cases the fine sands of the Pamunkey lie directly on the eroded surface of the Potomac formation, but this condition is unusual and local. The formation is not found in contact with the crystalline rocks. The sub-Pamunkey surface slopes eastward much more steeply than the upper surface of the same formation; on the Rappahannock near Fredericksburg the slope is 50 feet per mile, carrying the base of the Pamunkey from an altitude of 150 feet behind Falmouth to tide-level near the mouth of Massaponax Creek; and farther northward, between Potomac and Aquia creeks the rate is 100 feet per mile. This high inclination is, however, confined to the vicinity of the fall-line; farther eastward the slope diminishes considerably, though its amount is not known with accuracy. In addition to the eastward inclination the sub-Pamunkey surface displays many local irregularities. Thus, in a railway cut a mile south of Aquia Creek, there may be seen the cross-section of a channel 25 feet wide at the top, 10 feet wide at the railway level, and 25 feet deep, filled with Pamunkey deposits. The deposits are hard sands, weathered brown but exhibiting the usual characters of the weathered phase of the Pamunkey and contain indurated layers in which distinct Eocene fossils are clearly

recognizable. On the whole, it would appear that the sub-Pamunkey surface was more extensively trenched and eroded than that constituting the next higher unconformity.

The thickness of the formation is not definitely known. An exposure of 100 feet has been measured on Potomac River below the mouths of Aquia and Potomac creeks, and the summits of these beds are about 50 feet below the base of the Chesapeake formation. It is probable that in the eastern part of the Fredericksburg area the thickness of the formation (here altogether below tide) is about 300 feet. Toward the Piedmont margin the formation thins and disappears in feather edges or isolated outliers.

The abundant fossils of the formation are earlier Eocene, but the formation appears not to include representatives of the earliest Eocene found elsewhere in the province. In the Fredericksburg area the Pamunkey is the sole representative of a series which farther northward, as well as south of the Roanoke, comprises several distinct formations.

The Pamunkey formation, like the Chesapeake, is a typical marine deposit and gives a record of the geographic conditions under which it was laid down, while the unconformity at its base indicates with considerable clearness the immediately antecedent geography.

THE POTOMAC FORMATION.

The lowest and oldest formation of the Coastal Plain series is a heavy deposit of gravel and cobbles, sand, silt, and clay, called the Potomac formation, from the river on and near which it was first carefully studied. The deposit crops out only in a relatively small area in Stafford County and adjacent portions of Spottsylvania County, but it underlies the Pamunkey, Chesapeake, and Lafayette formations throughout the portion of the Coastal Plain shown on the Fredericksburg sheet. The deposits rest on the deeply eroded surface of the Piedmont crystallines, and are unconformably overlain by the Pamunkey and newer formations; the outcrops in the Fredericksburg area are confined to the limited tract from which these newer formations have been removed by erosion. This tract is about 5 miles wide at the northern margin of the Fredericksburg area; it gradually expands to 7 or 8 miles (measured along the waterway) on Aquia Creek, where its rocks are of considerable economic importance, and attains still greater width along Potomac Creek. In so far as the formation constitutes the surface, it then contracts to an irregular belt winding about the hills and valley sides to a little way south of Fredericksburg, where it terminates; but beneath the mantle of Columbia deposits it expands considerably in the Rappahannock valley, more or less continuous exposures appearing in the river cliffs from Falmouth to below the mouth of Massaponax Creek. It forms the surface again throughout a small tract about the fall-line on Massaponax Creek. There are also several isolated outliers in the highlands of the Piedmont scarp overlooking the Coastal Plain proper.

The most extensive exposures of the formation occur in the valley sides of Aquia, Accakeek, and Potomac creeks and along Hazel and Austin runs. Good exposures, revealing the structure of the formation, are found also along the Rappahannock opposite and below Fredericksburg. A noteworthy exposure, showing the various characteristics of the formation, occurs in the cliffs overlooking Potomac River at Cockpit Point, 5 miles north of the northern margin of the Fredericksburg area, this being the type example of the typical region in which the formation was defined and from which it was named.

The materials of the Potomac formation range from bowlder beds to porcelain clays. Sands and sandstones are the most prominent constituents, these, like other constituents, being variable in degree of comminution, structure, texture, and color. In general the sand is coarse, irregularly stratified and cross-bedded, slightly coherent, and light-gray in color. Commonly it consists of angular or subangular grains of quartz; and frequently, if not usually, these are associated with flakes or irregular particles of kaolin or fine white clay, which sometimes occurs in such abundance as to form a matrix in which the quartz grains are imbedded, though generally this element is less abundant, sufficing only to whiten the hands or the shovel and to give the sands a distinctive and easily recognized texture. This clay is, at least in large part, the product of decomposition of feldspar; and when the particles are large and angular or subangular (as is not infrequently the case), and when the associated quartz grains are also large and angular, the sand becomes a typical arkose. Although not always present, the arkosic aspect is characteristic of the Potomac sand. Commonly the sand beds contain coarser elements, usually in the form of well-rounded pebbles of quartzite, quartz, or clay; the rock pebbles being sometimes arranged in lines or strings, though sometimes irregularly disseminated, while the clay pebbles are usually either distributed irregularly or else arranged in strings and at the same time partially broken up and reduced to clay layers; and clay layers showing little or no trace of an original pebbly form, ranging from a fraction of an inch to several inches in thickness, are often found. Sometimes the rock pebbles are abundant, the sandy constituent being reduced to a matrix; again the sand largely disappears and the deposit is little more than a bed of pebbles or cobbles, sometimes (particularly near the base) containing bowlders a foot or more in diameter. In like manner, the pebbles and even the sand grains may disappear, when the deposit becomes a bed of blue or gray clay, commonly weathering white; these clay beds are sometimes of such purity as to be suitable for fine grades of pottery. Again the quartz grains may be assorted and separated both from clay and pebbles, forming local beds of clean sharp sand. Thus the constituents of the formation range from arkose to pebble beds, clay beds, and clean sand; but commonly these materials are intermixed, though in ever-varying proportions. In general the arkose occurs near the Piedmont crystallines, the assortment of the material increasing eastward; and in general also the pebble beds occur near the fall-line or near the larger rivers, the material being finer eastward and toward the divides. The composition of the pebbles also varies in a systematic way: along the Potomac, quartzite prevails, quartz being less abundant, while about the Rappahannock quartz prevails, quartzite being rare or absent. This distribution of materials indicates the origin of the deposit.

In structure the Potomac formation is irregularly stratified and, where sands prevail, notably cross-bedded. The texture varies with the principal constituents and also with the abundance of iron and other cementing elements; so that while the materials are commonly nearly or quite incoherent, they are locally cemented by iron or silica into firm sands, sandstones, or conglomerates. In the Fredericksburg area this is notably the case toward the mouth of Aquia Creek, where the arkosic and somewhat pebbly sands are cemented into a firm gray rock which has been largely used in construction. In the more clayey portions the iron is sometimes segregated in layers or nodules. The coloring is chiefly due to various oxides of iron; grays predominate, but yellow, brown, pink, red, purple, maroon, cream, snow-white, and various shades of blue and green are seen in separate bands or in mottlings. In general the arkosic sands and pebble beds occur in the lower part of the formation, the interbedded sands and clays toward the middle, and the light-gray sands and sandstones above.

The sandstones appear along the Rappahannock below Fredericksburg and in the lower beds of the formation about Falmouth; they are of great thickness along Potomac, Accakeek, and Aquia creeks. About Fredericksburg the sands are cross-bedded and of gray color, and contain pebbles of quartz with abundant grains of more or less decomposed feldspar, the pebbles being both scattered and in streaks. At higher levels in this vicinity more or less sandy laminated clays of rich and varied tints occur at intervals, mainly at horizons considerably above the base of the formation, and these not infrequently merge into sands. Such clays are well exposed on the river banks opposite Fredericksburg and in the slopes a mile and a half east of Falmouth, on Hazel Run, in the railway cutting a mile east of Stafford Court House, along the telegraph road a mile east of Garrisonville, 3 miles north of Garrisonville, and on the telegraph road at a point 3 miles north of Falmouth.

Along its western border in the Fredericksburg area, the Potomac formation abuts against a steep slope of crystalline rocks; farther eastward, as is known in part from borings in neighboring areas, the slope of the crystalline floor is much less; while the westernmost outliers occupy portions of the gently sloping plateau surface. The relations are such as to suggest a fault coinciding approximately with the fall-line, but the period of displacement has not been determined. By reason of the inequality of the floor on which the formation rests and the discontinuous character of the component beds, it is difficult to estimate the thickness of the formation. The exposures on Austin Run and along Potomac, Accakeek, and Aquia creeks, are about 200 feet thick; but it is probable that the aggregate thickness is considerably in excess of that shown in any single exposure.

Lignitized and silicified wood and fossil stems and leaves of plants, as well as distinct leaf impressions, occur in the clay beds of the formation. Notable localities of these fossils are on the railway between Aquia Creek and Brooke, and at Fredericksburg. The leaf impressions have been studied with special care, and have been found to represent a flora in which the archaic plant forms of the earth are intermixed with the dicotyledonous and other higher forms characteristic of the present as well as the later geologic ages. It is largely through these fossils that the age of the formation has been fixed as early Cretaceous. The great unconformity at the base of the Potomac formation and the lesser unconformity by which it is separated from the Pamunkey and newer formations, as well as the character and distribution of the deposits, yield a physical record of the formation which corroborates and extends the record found in the fossils; and thus the geologic history of the formation is fairly well known.

In other portions of the Coastal Plain, as well as in the Fredericksburg area, the Potomac formation has been found to constitute the base of the Coastal Plain series. Northward it thickens somewhat, and it undergoes other changes in Maryland, Delaware, Pennsylvania, and New Jersey; southward it is generally overlapped by newer formations of the series, but has been traced in successive outcrops through Virginia, North Carolina, South Carolina, Georgia, Alabama, and Mississippi, and its equivalents reappear with similar associations still farther westward. Partly by means of the fossil plants, a fairly definite succession of phases in the formation and of stages in the history has been worked out; but, in the Fredericksburg area at least, these phases are not sufficiently distinct to be traced on the ground or shown on the map with certainty.

THE CRYSTALLINE ROCKS.

The Piedmont province is made up of a complex series of ancient crystalline rocks. In the portion of this province included in the Fredericksburg area these are chiefly gneisses and granites, with a narrow belt of black slates, to which the name Quantico has been given, from the creek a few miles farther north.

The Piedmont gneisses are highly inclined, often standing nearly vertical; the prevailing trend is north-northeastward, or approximately parallel with the fall-line. Massive granite sheets and granitoid masses are intercalated with the gneisses; and there are occasional veins or dikes of quartz, also generally trending with the prevailing structure. These crystalline rocks are exposed in all the waterways crossing the fall-line within the Fredericksburg area, especially in the cascades through which the waters descend from the Piedmont province into the Coastal Plain, the rugged bowlders and ledges over which the waters of the Rappahannock dash and foam in their descent to Falmouth being typical.

The Quantico slates are exposed in the fall-line gorge of Aquia Creek, northeast of Garrisonville, and on Austin Run; they crop out on the road a mile east of Garrisonville; and they reappear a mile and a half east, and also half a mile south of Mountain View. The slate belt averages about three-quarters of a mile in width; north of Accakeek Creek it is the easternmost representative of the Piedmont crystallines, but south of that waterway the gneisses and granites recur east of the belt. On the west the Quantico slates appear to grade into siliceous mica-schist or gneisses of greenish-gray color, of such structure as easily to break into slabs of moderate thickness, this belt being 2 miles wide on Aquia Creek and Austin Run. Still farther westward coarse-grained granites occur; several dikes of feldspathic granite appear in the road cuttings north of Potomac Creek along the road to Mountain View.

The age of the Piedmont crystallines has not been accurately determined. The Quantico slates resemble the roofing slates on James River which carry lower Silurian fossils, though the resemblance may be fortuitous. The gneisses are commonly regarded as largely pre-Cambrian.

Except in the waterways, especially near the fall-line, the ancient crystallines are deeply decomposed and are consequently overlain by a thick residuary mantle of red or brown clays or loams. Through this mantle the harder ledges and quartz veins sometimes protrude; and in fresh exposures strings of quartz nodules and other structural lines are frequently seen passing from the undecomposed rock into the residuary clays. It is noteworthy that in the Piedmont-Potomac contacts the crystalline rocks are solid except where there are indications of post-Potomac decomposition, while in the Piedmont-Lafayette contacts the crystalline rocks are commonly decomposed. This relation bears on the geologic history of the region.

GEOLOGIC HISTORY OF THE COASTAL PLAIN.

The history of the Fredericksburg area is intimately connected with that of contiguous areas, and in part is interpreted thereby. The history falls into two portions, the first including the eras and episodes of accumulation, alteration, and degradation of the Piedmont rocks, and the second including the eras and episodes in the building of the Coastal Plain out of materials gathered largely from the Piedmont province. The earlier record is obscure and not yet fully interpreted; the later record is clearer, and although some of the minor episodes are obscure, the principal events have been interpreted. The principal movements are summarized in the accompanying table:

	EARTH-CRUST MOVEMENTS.	LOCAL MOVEMENTS.	GEOLOGIC PERIODS.
Piedmont and Coastal history.	Modern warping.	Fall-line gorge-cutting in the Piedmont, with accumulation of alluvium (mainly below tide), marsh growth, and talus-building in the Coastal Plain.	Recent.
	Post-Columbia uplift.	Trenching of the Columbia deposits, with development of minor details of the topography; interrupted by deposition in neighboring areas.	Pleistocene.
	Subsidence and warping.	Deposition of gravel, sand, loam, and ice-borne bowlders in terraces along the rivers (mechanical sediments); the Columbia formation.	
	Post-Lafayette uplift.	Cutting of gorges 200-300 feet deep in the Piedmont, and broad estuaries in the Coastal province; degradation of half the Lafayette deposits; shaping of the present topography.	Neocene.
	Subsidence with decided seaward tilting.	Degradation of residua and quartzose material in the Piedmont, and deposition of the material in the Coastal province, without fossils (mechanical sediments); the Lafayette formation.	
	Post-Chesapeake uplift.	Decomposition of Piedmont and Coastal rocks with feeble degradation and no valley-cutting.	
	Subsidence with little if any tilting.	Deposition of fine sand, clay, and glauconitic and diatomaceous deposits, with marine fossils (considerable chemical and vital reduction of sediments); the Chesapeake formation.	
	Post-Pamunkey uplift.	Moderate degradation in Piedmont and Coastal provinces, with general baseleveling.	
	Subsidence and slight seaward tilting.	Deposition of dark sands and marls with glauconite and marine fossils (partial chemical and vital reduction of sediments); the Pamunkey formation.	Eocene.
	Post-Potomac uplift.	Extensive degradation of Piedmont and Potomac formations, with cutting of moderately deep valleys; interrupted by deposition in neighboring areas.	Cretaceous.
	Subsidence and strong seaward tilting.	Deposition of gravel, arkose, sand, and fine clays, (mechanical sediments), with plants; the Potomac formation.	
Piedmont history.		Degradation of Piedmont and Newark rocks, and reduction of the province to present general form.	Early Mesozoic.
		Deposition of Newark sandstones, followed by deformation and igneous flows.	
		Greater part of degradation of Piedmont rocks.	
		Deposition of Piedmont sediments, followed by deformation, vulcanism, metamorphosis, etc.	Pre-Mesozoic.

The first episode in the building of the Coastal Plain began with a combined sinking and tilting of the land, so that the Atlantic encroached beyond the present fall-line, while at the same time the rivers were so stimulated that they gathered bowlders of quartzite from the Blue Ridge and of vein quartz from the Piedmont province and carried them down to the deeper estuaries, to be distributed by the storm waves of a steep and rocky coast; and on their way the bowlders were broken and worn to cobbles, peb-

bles, sand, and clay, which were dropped along shore or distributed by weight, the cobbles accumulating where the currents met, and the clay and sand finding their way into eddies and off-shore deeps where they were gathered into beds. The movement of the earth-crust was gradual, and as the ocean encroached on the land the beds of sand, arkose, and clay were laid one over the other in such manner that the later deposits extended the farther westward; and with the successive changes in geographic configuration the currents were shifted and some of the earlier sediments were torn up and redeposited. In this way the Potomac formation was built. About this time the archaic plant forms of the earlier geologic ages began to give place to the modern flora, and dinosaurs strayed along the shores. Meantime the rivers were swift and the storm waves and tidal currents strong, and aquatic organisms were rare and left little trace of their existence; but the leaves and other vegetal flotsam were lodged in the eddies and were in part entombed in the clays.

The next episode was one of degradation, represented by the unconformity between the Potomac and Pamunkey formations. During this period the land stood so high that the sea retreated beyond the Fredericksburg area, yet not so high as to permit the rivers greatly to deepen their channels. It was a period of baselevel planing, of sluggish degradation by the little rivulets toward the divides as well as by the great rivers in the valleys; and there were minor oscillations of such extent that in adjacent regions other deposits (notably the Severn formation of Maryland) were laid down. How far westward the Potomac sediments originally extended, and how great a volume of material was degraded during this epoch, are not known; but the configuration of the unconformity between the Potomac and Pamunkey deposits indicates that the Piedmont and Coastal zones were planed to a fairly uniform surface, with few deep valleys or ravines, and that the antecedent Piedmont waterways extended their courses over the nascent Coastal Plain in something like their present positions in the Fredericksburg area.

The next event in the building of the Coastal Plain was a subsidence of the land and adjacent sea-bottom, more uniform than the last, of such extent that the ocean again encroached as far as the modern fall-line; but the new-made sea-floor was fairly smooth and the seaward tilting was slight, so that the rivers were little stimulated and the storm waves weak, and thus the materials laid down in the encroaching waters were fine of grain and in part were reduced to stable chemic condition. For the same reasons marine life prevailed, as shown by the shells of mollusks and the teeth and bones of sharks imbedded in the deposits; rhizopods and other minute organisms abounded, as their remains attest, and some of them subsisted on the feldspathic débris brought in by the rivers, and through the assimilation of this material with their own substance produced grains and even great beds of glauconite. In this way the Pamunkey formation was built up of more or less oxidized sediments charged with organic remains.

Then came another epoch of degradation, during which the Pamunkey-Potomac surfaces, as well as the Piedmont zone, were lightly sculptured by rain and rivers into a baselevel plain even smoother than that below the Pamunkey. Minor oscillations during this period are recorded in other portions of the Coastal province, and these may have affected the Fredericksburg area; but the record here is blank, save as to the principal movement of the continent.

Once more a well-marked era was introduced by a subsidence of the land and contiguous sea-bottom, with little if any seaward tilting; the ocean pushed over the plain well toward the fall-line; and in the shoal waters by which the growing Coastal Plain was flooded, marine mollusks and predatory fishes abounded, while rhizopods continued to transmute feldspathic débris; and during a part of the period diatoms existed in such number that their shells formed a continuous bed intercalated with the chemically reduced sediments. In this way the Chesapeake formation was made.

From the Potomac period to the period of the Chesapeake, in the Fredericksburg area as elsewhere in the Coastal Plain, the epeirogenic history was one of oscillation of the land in which every downward movement was accompanied by seaward tilting; and from the Potomac to the Chesapeake the amplitude of the oscillations progressively diminished. With the diminution in movement of the earth-crust from era to era, the work of rains and rivers and waves decreased progressively, and the chemical agencies of decomposition and vital reconstruction increased relatively if not absolutely. This series of diminishing mechanical and increasing chemical activities continued after the deposition of the Chesapeake; for, while the land again lifted until the ocean retreated well toward the brink of the Coastal Plain, the lifting was so uniform that the rivers remained sluggish. Thus, while the next era was one of degradation, the stream work was feeble and decomposition of the rocks outran transportation, until the Piedmont province and parts of the adjacent zone were heavily mantled by residua; and no rocks save the chemically and mechanically obdurate quartzite of the eastern Appalachians and quartz of the Piedmont veins remained within reach of the streams. During this time the Piedmont province was a low-lying plain; most of the rivers flowed along the present lines, but they meandered idly through shallow valleys instead of rushing through sharp-cut gorges as at present. In this way the gently undulating plain now constituting the Piedmont Plateau, and the nearly level plain of the sub-Lafayette unconformity in the Coastal province, were fashioned.

At the end of this era of stable land and preponderant chemical action, the diminishing series of oscillations beginning with Cretaceous time came to an end and a new series of earth-crust movements began.

The next episode was introduced by a strong warping of the earth-crust, whereby the interior was lifted and the shoreward periphery depressed; and the subsidence so far predominated that the ocean encroached on the erstwhile land somewhat beyond the fall-line. Through the tilting of the land the sluggish rivers were vivified and scoured their channels, transporting the chemically obdurate quartzite and quartz into the sea, while the rapidly retroceding rivulets kept the waters charged with the friable residuary clays and loams. In this way the waves were fed by chemically stable material in which the coarse and the fine were intermingled in unusual fashion. Through this combination of causes and antecedent conditions the widespread and singularly uniform Lafayette formation was built.

The next record is one of degradation; and as the continent-movement initiating Lafayette deposition was more energetic than for ages, so in about the same ratio was the post-Lafayette uplift energetic and ample. The land was lifted so high that the ocean retreated to or beyond the brink of the Coastal Plain, and the rivers excavated great estuaries through this province and carved the steep-sided Piedmont and Appalachian gorges. This attitude of the land persisted not only until the Coastal Plain waterways cut through the Lafayette formation, but until many of them sawed their way scores and even hundreds of feet into the underlying formations, and until at least half of the aggregate volume of the Lafayette deposits was carried away, leaving the formation as a series of remnants only. It was chiefly during this period of high level that the hills and valleys of the Fredericksburg area were shaped and the outcrops of the different formations determined.

It is probable that after this episode of active erosion the land gradually assumed about its present level. Then another stage was introduced by a subsidence of the land in mid-latitudes and the beginning of a series of ice-invasions in northern United States. While the land stood low in the latitude of Rappahannock River, the climate was somewhat changed, the ice froze thick and probably the snow fell deep, and during the vernal freshets bowlders of exceptional size and clays and loams in exceptional quantity were carried into the estuaries by the ice-floes and waters; but in the Fredericksburg area the subsidence was such as to flood only the lower lands. By these freshets and the tidal currents of the estuaries the Columbia deposits were accumulated and the broad terraces flanking the Rappahannock and the Potomac were built.

In the last stage of the history clearly recorded in the deposits and earth-forms of the Fredericksburg area, the land and sea-bottom were again lifted so far as to permit the principal waterways to cut into or through the Columbia deposits, and this lifting was followed by slight subsidence which ran into the present sinking of the Coastal Plain.

ECONOMIC PRODUCTS.

The principal mineral products of the Fredericksburg region consist of building stones, marl, fuller's earth, brick clay, pottery clay, sand, quartz-gravel, and underground waters.

Building stones.—The sandstones of the Potomac formation were extensively quarried for building stones years ago, and furnished a portion of the materials for the Executive Mansion and other buildings in Washington. They are now used locally in small amount. The principal quarries were on the northern bank of Aquia Creek, a short distance above the railroad bridge, and on the opposite bank 2 miles farther up the creek. Stone has been quarried also on Austin Run and in the vicinity of Fredericksburg. The sandstones are somewhat fragile and irregular in structure and composition. The supply is large, and the stone is easily quarried, so that it will always be of local use.

The crystalline rocks are used locally for rough building and underpinning, but they are not quarried for shipment. The siliceous layers in the Pamunkey formation in the vicinity of Stafford Court House, near Moss Neck, and on Marlboro Point, are suitable for local use and have been quarried to a small extent. In the eastern part of the area of the Fredericksburg sheet, rocks are very scarce, and the occasional thin strata of sandy ironstone which occur in the Lafayette formation have yielded material for foundations.

Marl.—The most important mineral resource in the area of the Fredericksburg sheet is marl, large deposits of which exist in the Pamunkey and Chesapeake formations. The Pamunkey formation consists in greater part of marl, and the shell marls which are contained in the Chesapeake formation in Caroline County are of considerable extent and thickness. These marls contain lime and potash in small percentages and usually also some phosphoric acid. They are of great value for enriching land and especially for restoring the fertility of worn-out soils. They have not been extensively used in the region, but a number of farmers have tested their efficacy with most satisfactory results. In some other portions of the Coastal Plain province they are in general use and their great value is fully recognised. This is particularly the case in New Jersey, where the marls are dug in large amounts for local use and are to some extent shipped to points outside of the marl belt. The marls are not so powerful and prompt as the chemical fertilizers, but their effect is gradual and more lasting and they do not ultimately exhaust the soil. The fertilizing influence continues for several years, and the land will bear many successive treatments. As the marls underlie the greater portion of the region and are easy to excavate, the expense attending their use is very small compared with the benefit to be delivered from them. All sandy soils and nearly all crops have been found to be benefited by marls. Grasses, grain, and corn are particularly subject to its influence and in many cases have been found to yield from 30 to 40 per cent more after the soil had been lightly overspread with marl.

The marl is usually a sand containing grains of the dark-green mineral glauconite (which consists in part of potash) with more or less carbonate of lime in a fine powder and as shells. There is usually a considerable admixture of clay. The Chesapeake marls consist largely of clay and fine sand. The Pamunkey marls vary considerably in strength, and the black, red, and brown members are of little value, though richly glauconitic shell marls abound in the formation. Just east of Brooke these marls are worked for admixture with fish and other fertilizers.

More or less highly glauconitic shell marls are extensively exposed in the high bluffs of Potomac River below the mouths of Aquia and Potomac creeks, and they are plentiful in the gullies back from the river, from the mouth of Potomac Creek to Mathias Point. The marls are often exposed in the upper part of the Machodoc Creek depression, on both sides of Rappahannock River and up its side branches nearly to Port Royal, and along Mattapony River below Milford. In the Rappahannock valley the marl outcrop is mainly in the slopes behind the river terraces, but it is also exposed at various points along the river banks and in small stream cuts through the terrace deposits. From the mouth of Mattaponax Creek to Port Royal exposures are frequent and often extensive. In Charles County, Maryland, the marls are highly calcareous. They are finely exposed along Potomac River in the banks just above Clifton Beach and for some distance northward, and in the depressions about Port Tobacco, and westward in many gullies to the vicinity of Hilltop. Along the western edge of the Pamunkey formation and in old surface outcrops the marls are usually quite deeply weathered to buff or red sands which have lost the greater part, if not all, of their fertilizing power, and eastward the upper beds of the formation are mainly black sands without shells or glauconite. In many slopes the marls are covered by wash or débris of greater or less thickness, but behind this superficial covering, and in gullies where erosion is rapid, the marl may be looked for throughout the area of the Pamunkey formation as represented on the map, with the exceptions above noted. In selecting marl it should be remembered that the portions containing the largest proportions of shells and grains of the dark, bottle-green mineral, glauconite, are richest in plant food.

Fuller's or infusorial earth.—Eastward in the Chesapeake formation the beds of diatomaceous remains are often sufficiently pure for commercial use as "fuller's earth." The largest deposits are near the base of the formation, and they are best exposed in the bluffs along the Potomac at the mouth of Port Tobacco River and in the bluffs along Rappahannock River in the southwestern corner of Westmoreland County. The deposits also underlie the eastern part of King George and Essex counties, and they are exposed at many points along streams and in road cuts. The purity of the material is diminished in some portions of the district by admixture with clay or sand, but over much of the area there are large supplies of relatively pure deposits.

Brick Clays.—The loams of the Columbia formation, and to a less extent those of the Lafayette formation, are used locally for brickmaking. The deposits are nearly coextensive with the formations, and they are generally well adapted for brickmaking. The Columbia loam is especially valuable for this purpose, as shown by experience in neighboring tracts. Washington and Baltimore are largely built of bricks made from this deposit; in Philadelphia and Trenton the same deposit (locally known as Philadelphia Brick Clay) is extensively developed, and the material is largely used in these and neighboring cities; and the loam forming the terraces of Rappahannock River at and below Fredericksburg is equally adapted to the manufacture of ordinary and pressed bricks, and is practically unlimited in quantity.

Some portions of the Quantico slates are similar to the slates elsewhere employed for the manufacture of fire-brick, which is coming into extensive use for paving and other purposes; but the Quantico material has not yet been tested.

Pottery.—Some of the clays in the Potomac formation about Fredericksburg, and along the Rappahannock below, are probably of the proper character for the manufacture of pottery, tiling, and terra-cotta, but so far as known they have not been tested.

Sand.—The lower or middle beds of the Columbia formation are made up largely of sand, which is frequently of such character as to excel as building sand. Building sands are also found locally in the lower part of the Lafayette formation, and at various horizons in the Potomac formation. The Potomac sands often require screening, but after passing through this process they are usually excellent, consisting of sharp grains of firm quartz; such sand is highly valued among the builders of neighboring cities. Molding sand of good quality is found in the Chesapeake in the adjacent portions of the Coastal Plain, and will doubtless be a useful resource in the Fredericksburg tract.

Gravel.—The gravel beds found in the Lafayette formation are a rich source of most excellent

material for road-making and railway ballasting, and their use can not be too strongly advocated. The well-rounded quartz pebbles are easily handled and transported, and are practically indestructible. The coarser gravels and cobbles of the Potomac are equally useful, and are bound to come into use as material for paving, guttering, and other road-making uses.

Underground waters.—In the Coastal Plain area on the Fredericksburg sheet the water supplies are derived from shallow wells, springs, and surface streams. Where there is no contamination from drains, barnyards, and other sources of similar impurity the waters are often of satisfactory quality, but it is probable that much of the malaria so prevalent in the lower lands is derived from waters on or near the surface. In many places in eastern Virginia wells have been sunk to deeper-seated waters, and it is found in most cases that a marked diminution in malarial diseases has resulted. These deeper-seated waters underlie all of the Coastal Plain area of the Fredericksburg sheet, at depths which vary from 100 to 700 feet. To the eastward there are several horizons, including those which yield water to many wells farther down the Rappahannock valley and to wells at Colonial Beach.

The principal horizons are in the Potomac and Pamunkey formations, and consist of coarse sands or gravels in thin and widely extended sheets which dip gently eastward. The Potomac horizons underlie the entire region southeast and east of the crystalline rock outcrops, but their easterly dip carries them far beneath the surface along the eastern margin of the area. In the eastern portions of Stafford and Spottsylvania counties they may be expected to yield water at depths of from 100 to 200 feet. The principal water-bearing stratum lies on the eastward-dipping floor of crystalline rocks, and water probably will be found at various horizons in the sand beds above.

In the basal beds of the Pamunkey formation there are waters in the region lying east of a line from Liverpool Point to the mouth of Massaponax Creek and the vicinity of Bowling Green. The water-bearing bed dips eastward at a rate of about 10 feet per mile, so that it lies about 250 feet below tide-water level along the eastern border of the tract. It may be expected to furnish large supplies of pure or slightly sulphurous waters, which will rise about 25 feet above tide-level along Rappahannock River. At Chapel Point this water was found at a depth of 237 feet, and at Colonial Beach at 250 feet.

At the base of the Columbia and Lafayette deposits there are widely extended beds of gravels and coarse sands which furnish water to hundreds of shallow wells. The supply at the base of the Columbia formation, which occurs at low levels, is particularly abundant; while wells finding their supply at the base of the Lafayette are notably persistent. The ground waters of both of these horizons are of great importance to the people of the Fredericksburg tract; yet precaution is necessary in utilizing them, since both are liable to surface contamination. The Lafayette deposits are chemically stable and notably pervious, and water passing through them is filtered mechanically, but not necessarily freed from organic impurities; and in somewhat less degree the same is true of the Columbia deposits. Wells taking water from these deposits are safe only when removed so far as may be from houses, barns, stock yards, privies, and other possible sources of contamination.

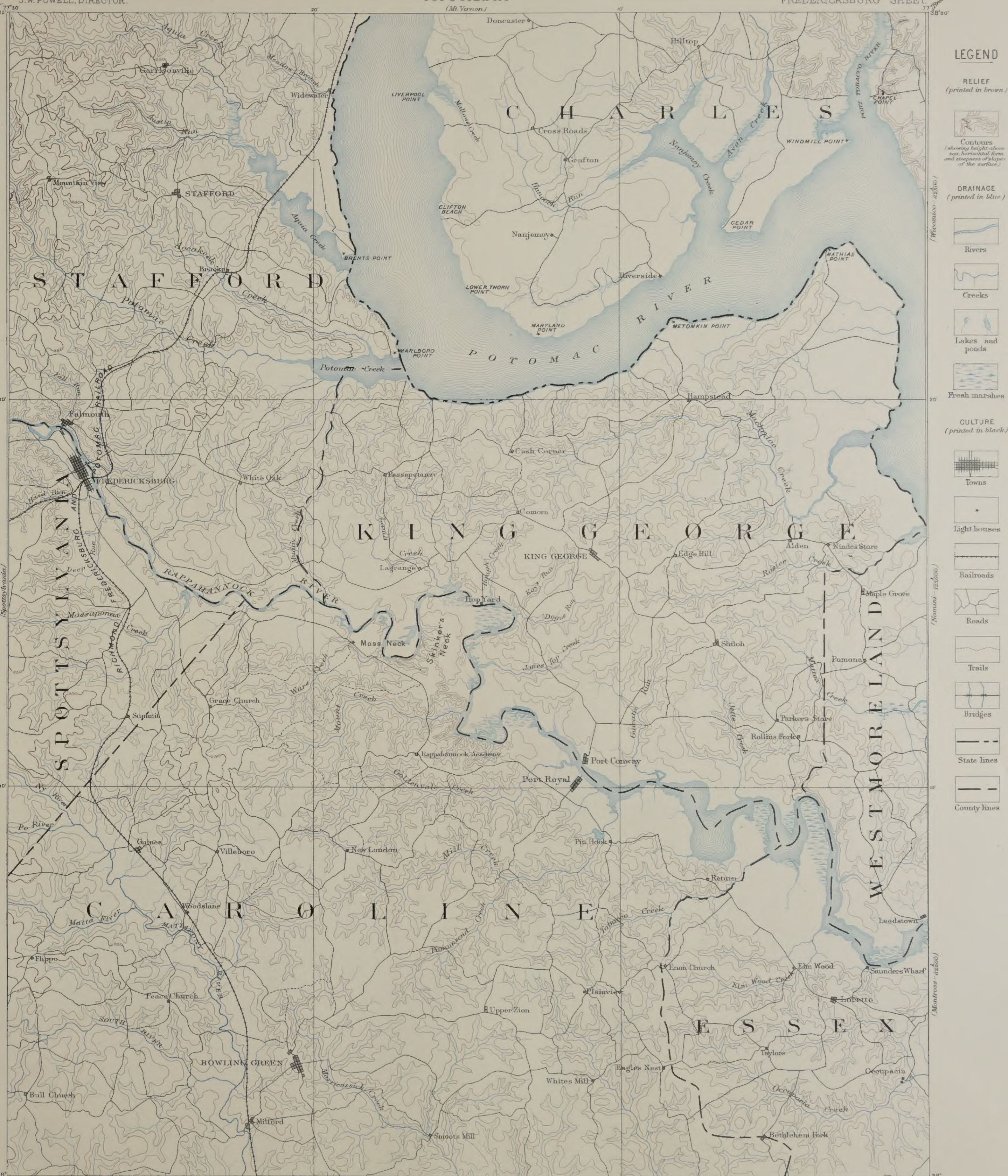
N. H. DARTON,
Geologist.

W J McGEE,
Geologist in charge.

U.S. GEOLOGICAL SURVEY.
J.W. POWELL, DIRECTOR.

TOPOGRAPHY

VIRGINIA-MARYLAND
FREDERICKSBURG SHEET



Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation and Shore Lines by the U.S.Coast and Geodetic Survey.
Topography by E.C.Barnard and D.C.Harrison.
Surveyed in 1887-8.

Harrison
Barnard

Scale $\frac{1}{125000}$

0 1 2 3 4 5 6 Miles

Contour Interval 50 feet

Datum is mean Sea level

Edition of Oct. 1894.

AREAL GEOLOGY

VIRGINIA-MARYLAND
FREDERICKSBURG SHEET

Henry Gannett, Chief Geographer.
Gilbert Thompson, Geographer in charge.
Triangulation and Shore Lines by the U.S. Coast and Geodetic Survey.
Topography by E.C. Barnard and D.C. Harrison.
Surveyed in 1887-8.

Harrison
Barnard

Scale 1/125000
0 1 2 3 4 5 6 Miles
Contour Interval 50 feet
Datum is mean Sea level

Edition of Oct. 1894.

G.K. Gilbert, Chief Geologist.
W J Mc Gee, Geologist in Charge.
Geology by N.H. Darton.
Surveyed in 1890.

pour out of cracks and volcanoes and flow over the surface as lava. Sometimes they are thrown from volcanoes as ashes and pumice, and are spread over the surface by winds and streams. Often lava flows are interbedded with ash beds.

It is thought that the first rocks of the earth, which formed during what is called the Archean period, were igneous. Igneous rocks have intruded among masses beneath the surface and have been thrown out from volcanoes at all periods of the earth's development. These rocks occur therefore with sedimentary formations of all periods, and their ages can sometimes be determined by the ages of the sediments with which they are associated.

Igneous formations are represented on the geologic maps by patterns of triangles or rhombs printed in any brilliant color. When the age of a formation is not known the letter-symbol consists of small letters which suggest the name of the rocks; when the age is known the letter-symbol has the initial letter of the appropriate period prefixed to it.

(4) *Altered rocks of crystalline texture.*—These are rocks which have been so changed by pressure, movement and chemical action that the mineral particles have recrystallized.

Both sedimentary and igneous rocks may change their character by the growth of crystals and the gradual development of new minerals from the original particles. Marble is limestone which has thus been crystallized. Mica is one of the common minerals which may thus grow. By this chemical alteration sedimentary rocks become crystalline, and igneous rocks change their composition to a greater or less extent. The process is called *metamorphism* and the resulting rocks are said to be metamorphic. Metamorphism is promoted by pressure, high temperature and water. When a mass of rock, under these conditions, is squeezed during movements in the earth's crust, it may divide into many very thin parallel layers. When sedimentary rocks are formed in thin layers by deposition they are called *shales;* but when rocks of any class are found in thin layers that are due to pressure they are called *slates.* When the cause of the thin layers of metamorphic rocks is not known, or is not simple, the rocks are called *schists,* a term which applies to both shaly and slaty structures.

Rocks of any period of the earth's history, from the Neocene back to the Algonkian, may be more or less altered, but the younger formations have generally escaped marked metamorphism, and the oldest sediments known remain in some localities essentially unchanged.

Metamorphic crystalline formations are represented on the maps by patterns consisting of short dashes irregularly placed. These are printed in any color and may be darker or lighter than the background. If the rock is a schist the dashes or hachures may be arranged in wavy parallel lines.

If the formation is of known age the letter-symbol of the formation is preceded by the capital letter-symbol of the proper period. If the age of the formation is unknown the letter-symbol consists of small letters only.

USES OF THE MAPS.

Topography.—Within the limits of scale the topographic sheet is an accurate and characteristic delineation of the relief, drainage and culture of the region represented. Viewing the landscape, map in hand, every characteristic feature of sufficient magnitude should be recognizable.

It may guide the traveler, who can determine in advance or follow continuously on the map his route along strange highways and byways.

It may serve the investor or owner who desires to ascertain the position and surroundings of property to be bought or sold.

It may save the engineer preliminary surveys in locating roads, railways and irrigation ditches.

It provides educational material for schools and homes, and serves all the purposes of a map for local reference.

Areal geology.—This sheet shows the areas occupied by the various rocks of the district. On the margin is a *legend,* which is the key to the map. To ascertain the meaning of any particular colored pattern on the map the reader should look for that color and pattern in the legend, where he will find the name and description of the formation. If it is desired to find any given formation, its name should be sought in the legend and its colored pattern noted, when the areas on the map corresponding in color and pattern may be traced out.

The legend is also a partial statement of the geologic history of the district. The formations are arranged in groups according to origin—superficial, sedimentary, igneous or crystalline; thus the processes by which the rocks were formed and the changes they have undergone are indicated. Within these groups the formations are placed in the order of age so far as known, the youngest at the top; thus the succession of processes and conditions which make up the history of the district is suggested.

The legend may also contain descriptions of formations or of groups of formations, statements of the occurrence of useful minerals, and qualifications of doubtful conclusions.

The sheet presents the facts of historical geology in strong colors with marked distinctions, and is adapted to use as a wall map as well as to closer study.

Economic geology.—This sheet represents the distribution of useful minerals, the occurrence of artesian water, or other facts of economic interest, showing their relations to the features of topography and to the geologic formations. All the geologic formations which appear on the map of areal geology are shown in this map also, but the distinctions between the colored patterns are less striking. The areal geology, thus printed, affords a subdued background upon which the areas of productive formations may be emphasized by strong colors.

A symbol for mines is introduced in this map, and it is accompanied at each occurrence by the name of the mineral mined or the stone quarried.

Structure sections.—This sheet exhibits the relations existing beneath the surface among the formations whose distribution on the surface is represented in the map of areal geology.

In any shaft or trench the rocks beneath the surface may be exposed, and in the vertical side of the trench the relations of different beds may be seen. A natural or artificial cutting which exhibits those relations is called a *section,* and the same name is applied to a diagram representing the relations. The arrangement of rocks in the earth is the earth's *structure,* and a section exhibiting this arrangement is called a *structure section.*

Mines and tunnels yield some facts of underground structure, and streams carving canyons through rock masses cut sections. But the geologist is not limited to these opportunities of direct observation. Knowing the manner of the formation of rocks, and having traced out the relations among beds on the surface, he can infer their relative positions after they pass beneath the surface. Thus it is possible to draw sections which represent the structure of the earth to a considerable depth and to construct a diagram exhibiting what would be seen in the side of a trench many miles long and several thousand feet deep. This is illustrated in the following figure:

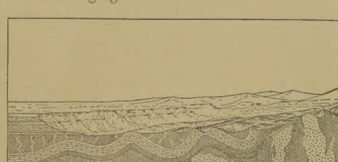


Fig. 2. Showing a vertical section in the front of the picture, with a landscape above.

The figure represents a landscape which is cut off sharply in the foreground by a vertical plane. The landscape exhibits an extended plateau on the left, a broad belt of lower land receding toward the right, and mountain peaks in the extreme right of the foreground as well as in the distance. The vertical plane cutting a section shows the underground relations of the rocks. The kinds of rock are indicated in the section by appropriate symbols of lines, dots, and dashes. These symbols admit of much variation, but the following are generally used in sections to represent the commoner kinds of rock:

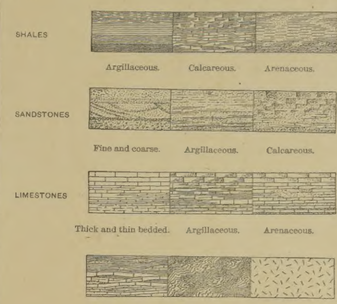


Fig. 3. Symbols used to represent different kinds of rocks.

The plateau in Fig. 2 presents toward the lower land an escarpment which is made up of cliffs and steep slopes. These elements of the plateau-front correspond to horizontal beds of sandstone and sandy shale shown in the section at the extreme left, the sandstones forming the cliffs, the shales constituting the slopes.

The broad belt of lower land is traversed by several ridges, which, where they are cut off by the section, are seen to correspond to outcrops of sandstone that rise to the surface. The upturned edges of these harder beds form the ridges, and the intermediate valleys follow the outcrops of limestone and calcareous shales.

Where the edges of the strata appear at the surface their thicknesses can be measured and the angles at which they dip below the surface can be observed. Thus their positions underground can be inferred.

When strata which are thus inclined are traced underground in mining or by inference, it is frequently observed that they form troughs or arches, such as the section shows. But these sandstones, shales and limestones were deposited beneath the sea in nearly flat sheets. Where they are now bent they must, therefore, have been folded by a force of compression. The fact that strata are thus bent is taken as proof that a force exists which has from time to time caused the earth's surface to wrinkle along certain zones.

The mountain peaks on the right of the sketch are shown in the section to be composed of schists which are traversed by masses of igneous rock. The schists are much contorted and cut up by the intruded dikes. Their thickness cannot be measured; their arrangement underground cannot be inferred. Hence that portion of the section which shows the structure of the schists and igneous rocks beneath the surface delineates what may be true, but is not known by observation.

Structure sections afford a means of graphic statement of certain events of geologic history which are recorded in the relations of groups of formations. In Fig. 2 there are three groups of formations, which are distinguished by their subterranean relations.

The first of these, seen at the left of the section, is the group of sandstones and shales, which lie in a horizontal position. These sedimentary strata, which accumulated beneath water, are in themselves evidence that a sea once extended over their expanse. They are now high above the sea, forming a plateau, and their change of elevation shows that that portion of the earth's mass on which they rest swelled upward from a lower to a higher level. The strata of this group are parallel, a relation which is called *conformable.*

The second group of formations consists of strata which form arches and troughs. These strata were continuous, but the crests of the arches have been removed by degradation. The beds, like those of the first group, being parallel, are conformable.

The horizontal strata of the plateau rest upon the upturned, eroded edges of the beds of the second group on the left of the section. The overlying deposits are, from their position, evidently younger than the underlying formations, and the bending and degradation of the older strata must have occurred between the deposition of the older beds and the accumulation of the younger. When younger strata thus rest upon an eroded surface of older strata or upon their upturned and eroded edges, the relation between the two is *unconformable,* and their surface of contact is an *unconformity.*

The third group of formations consist of crystalline schists and igneous rocks. At some period of their history the schists have been plicated by pressure and traversed by eruptions of molten rock. But this pressure and intrusion of igneous rocks have not affected the overlying strata of the second group. Thus it is evident that an interval of considerable duration elapsed between the formation of the schists and the beginning of deposition of strata of the second group. During this interval the schists suffered metamorphism and were the scene of eruptive activity. The contact between the second and third groups, marking an interval between two periods of rock formation, is an unconformity.

The section and landscape in Fig. 2 are hypothetical, but they illustrate only relations which actually occur. The sections in the Structure Section sheet are related to the maps as the section in the figure is related to the landscape. The profiles of the surface in the section correspond to the actual slopes of the ground along the section line, and the depth of any mineral-producing or water-bearing stratum which appears in the section may be measured from the surface by using the scale of the map.

Columnar sections.—This sheet contains a concise description of the rock formations which constitute the local record of geologic history. The diagrams and verbal statements form a summary of the facts relating to the characters of the rocks, to the thicknesses of sedimentary formations and to the order of accumulation of successive deposits.

The characters of the rocks are described under the corresponding heading, and they are indicated in the columnar diagrams by appropriate symbols, such as are used in the structure sections.

The thicknesses of formations are given under the heading "Thickness in feet," in figures which state the least and greatest thicknesses. The average thickness of each formation is shown in the column, which is drawn to a scale,—usually 1,000 feet to 1 inch. The order of accumulation of the sediments is shown in the columnar arrangement of the descriptions and of the lithologic symbols in the diagram. The oldest formation is placed at the bottom of the column, the youngest at the top. The strata are drawn in a horizontal position, as they were deposited, and igneous rocks or other formations which are associated with any particular stratum are indicated in their proper relations.

The strata are divided into groups, which correspond with the great periods of geologic history. Thus the ages of the rocks are shown and also the total thickness of deposits representing any geologic period.

The intervals of time which correspond to events of uplift and degradation and constitute interruptions of deposition of sediments may be indicated graphically or by the word "unconformity," printed in the columnar section.

Each formation shown in the columnar section is accompanied, not only by the description of its character, but by its name, its letter-symbol as used in the maps and their legends, and a concise account of the topographic features, soils, or other facts related to it.

J. W. POWELL,
Director.